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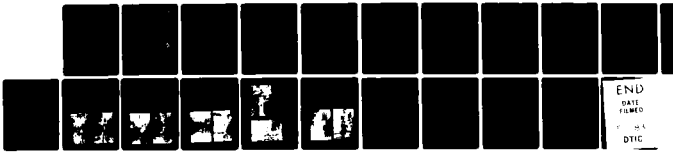

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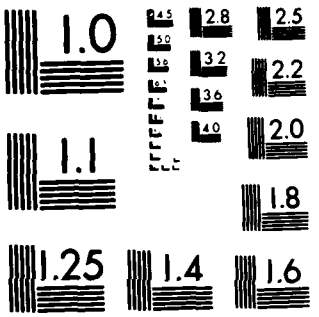

Technical Report E06516-4
Contract No. N00039-81-C-0357

IITRI

MEASURED ELECTROMAGNETIC FIELDS AT ELF COMMUNICATIONS PROGRAM ECOLOGICAL STUDY PLOTS: SLIME MOLD STUDIES IN THE CHEQUAMEGON NATIONAL FOREST, WISCONSIN

J. Enk

February 1983

Prepared for

U.S. Naval Electronic Systems Command
Washington, D.C.

Submitted by

IIT Research Institute
10 West 35th Street
Chicago, Illinois 60616

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REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1 REPORT NUMBER	2. GOVT ACCESSION NO. A126 911	3. RECIPIENT'S CATALOG NUMBER
4 TITLE (and Subtitle) MEASURED ELECTROMAGNETIC FIELDS AT THE ELF COMMUNICATIONS PROGRAM ECOLOGICAL STUDY PLOTS: SLIME MOLD STUDIES IN THE CHEQUAMEGON NATIONAL FOREST, WISCONSIN		5. TYPE OF REPORT & PERIOD COVERED Technical September 1982
		6. PERFORMING ORG. REPORT NUMBER E06516-4
7. AUTHOR(s) J. Enk		8. CONTRACT OR GRANT NUMBER(s) N00039-81-C-0357
9 PERFORMING ORGANIZATION NAME AND ADDRESS IIT Research Institute 10 West 35th Street Chicago, IL 60616		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS U.S. Naval Electronic Systems Command, PME 110-EB Washington, DC 20360		12. REPORT DATE February 1983
		13. NUMBER OF PAGES 20
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Unlimited Distribution

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19 KEY WORDS (Continue on reverse side if necessary and identify by block number)

Extremely Low Frequency (ELF)
Physarum Polycephalum
Electromagnetic Fields
Electromagnetic Radiation
Biological Effects

20 ABSTRACT (Continue on reverse side if necessary and identify by block number)

Measured electromagnetic fields at locations selected by investigators for studying ELF effects on the slime mold, physarum polycephalum, are reported. Electric and magnetic fields at the ELF communications frequency (76 Hz) and ambient fields produced by 60 Hz sources are described for paired test (near antenna) and control (remote from antenna) study plots, and conform with established exposure criteria for studying electromagnetic effects on ecological communities.

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FOREWORD

This report documents the extremely low frequency (ELF) electromagnetic field measurements made at test and control plots in the Chequamegon National Forest selected for study of the effects of long term exposure of slime mold (physarum polycephalum) to the U.S. Navy ELF Communications system. The slime mold study, being conducted by the University of Wisconsin - Parkside researchers, and the measurements described herein are in support of the ELF Communications Program and were funded under provisions of Contract No. N00039-81-C-0357. The electromagnetic measurements were performed by J. Gauger, Dr. J. Zapotosky, and J. Enk all of IIT Research Institute (IITRI) during 22-24 September 1982.

Respectfully submitted,

IIT RESEARCH INSTITUTE

J. O. Enk
Associate Engineer

APPROVED:

R. D. Carlson
Program Manager

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MEASURED ELECTROMAGNETIC FIELDS AT ELF COMMUNICATIONS PROGRAM ECOLOGICAL STUDY PLOTS: SLIME MOLD STUDIES IN THE CHEQUAMEGON NATIONAL FOREST, WISCONSIN

1. INTRODUCTION

To assure understanding of the long term effects of operating an Extremely Low Frequency (ELF) communications system on nearby ecological communities, the Naval Electronic Systems Command has established an Ecological Monitoring Program to study a variety of sensitive species in the vicinity of its ELF transmitting facilities, both present and planned. This program is being conducted by numerous investigators in Wisconsin and Michigan under subcontracts to IIT Research Institute, which provides overall program management, and electromagnetic measurement and engineering support. The Ecological Monitoring Program was initiated in 1982 and is expected to continue for several years. Reports of the individual ecological studies and an overall summary report will be published on an annual basis.

The extremely low frequency electromagnetic fields produced by ELF transmitting antennas have intensities in air and in earth that approximate those attributable to commercial power systems. Since the purpose of the Ecological Monitoring Program is to detect whether unexpected ecological effects might result from long-term ELF Communications Systems operations, it is important that fields produced by ELF antennas are distinguishable from the ambient electromagnetic fields at locations selected for studying ecological effects. Certain criteria have therefore been established as reasonable goals so that rational interpretations of the results of studies can be made. These electromagnetic criteria are not absolute requirements, however, because other important factors also influence the selection of study plots. IITRI is assisting its subcontractors by measuring the electromagnetic fields at candidate study sites so that appropriate plot selections are made.

Investigators from the University of Wisconsin (Parkside) will study the slime mold (physarum polycephalum) at test and control plots in northern Wisconsin as a part of the ELF Ecological Monitoring Program. The plots selected by the investigators are identified in Figure 1. Their locations are given in greater detail in Appendix A. In September 1982, IITRI engineering

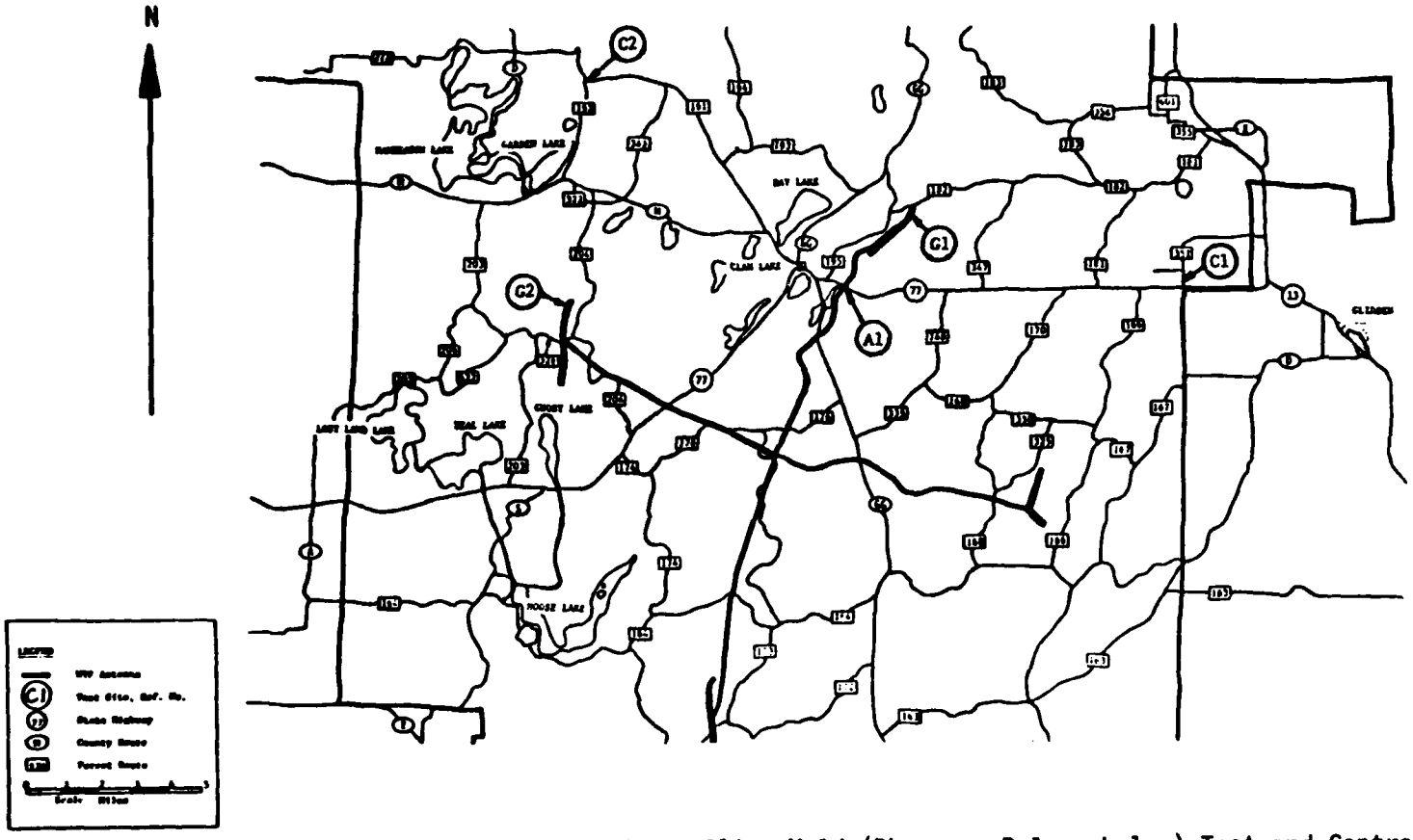


Figure 1 - Location of the Slime Mold (Physarum Polycephalum) Test and Control Sites in the Area Surrounding the Wisconsin Test Facility Located in the Chequamegon National Forest.

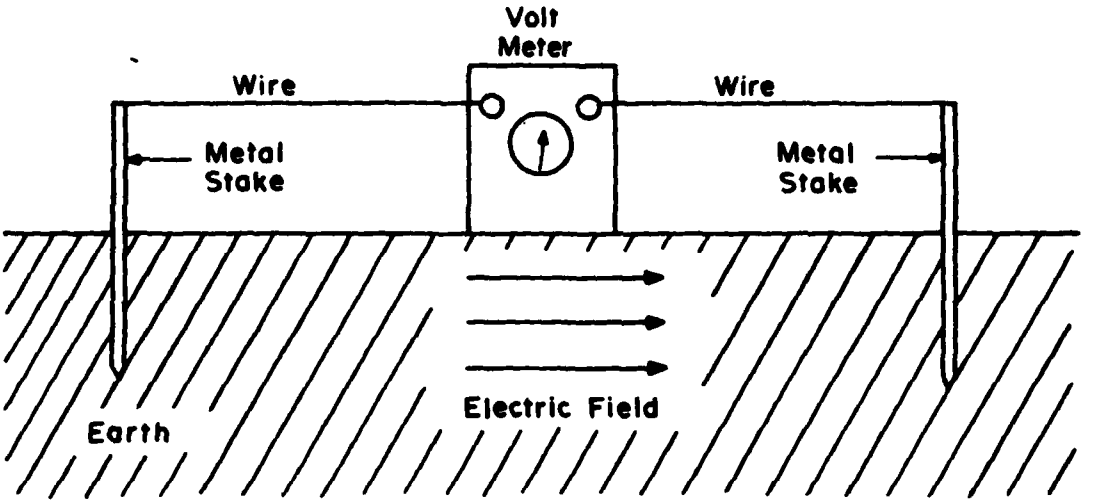
personnel visited these sites to measure the electric and magnetic fields of interest as a partial evaluation of their suitability for the intended biological research. The measurement techniques employed and the data obtained are described in the following paragraphs.

2. ELECTRIC AND MAGNETIC FIELD MEASUREMENTS

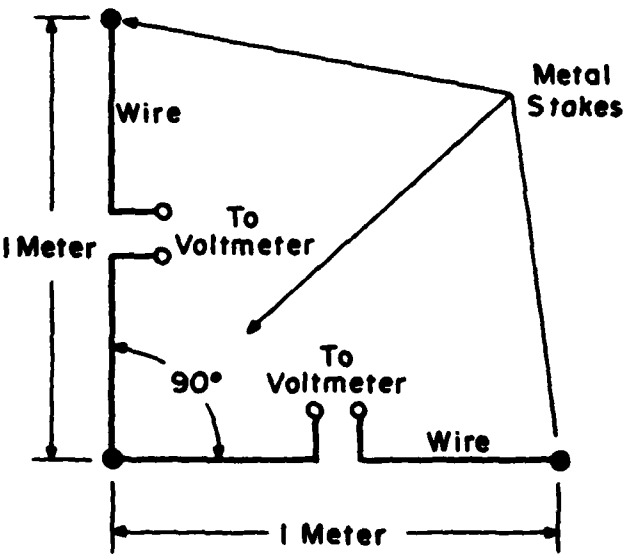
Slime molds prefer moist places with little or no sunlight. They can be found near rotting logs and other vegetation in shady, relatively wet places. The electric and magnetic fields present in the earth are therefore the important electromagnetic factors in slime mold studies, and electric fields in air are unimportant since other vegetation effectively shields the slime mold from their influence.

The electric fields present in the earth were measured with one-meter probe wires using a methodology and geometry as indicated in Figure 2. Two perpendicular components of the horizontal field were measured and the field magnitude was calculated as the square root of the sum of the squares of the measured components. A Hewlett-Packard HP3581A signal wave analyzer was used to accurately measure the probe wire output. The HP3581A functions as a frequency selective voltmeter, and for these data was used with a measurement bandwidth of 3 Hz to discriminate between 60 Hz and 76 Hz fields. The electric field data obtained at the slime mold test and control sites is summarized in Section 3 below. A more complete representation of the data, indicating each field component recorded, is given in Appendix B.

The magnetic field was measured using a calibrated single axis magnetic field probe designed and built by IITRI. This probe is a many-turned coil with a ferrite core and terminating resistor. Appropriate conversion factors were used to convert the voltage reading at the output of the probe to an equivalent magnetic flux density. A summary of the measured magnetic flux densities at the test and control sites for 76 Hz and ambient 60 Hz fields is given in Section 3. For each frequency and antenna condition the field was measured in three perpendicular directions (north-south, east-west, and vertical), and the field magnitude was computed as the square root of the sum of the squares of these components. The 60 Hz values were measured with the



a) Measuring A Horizontal Electric Field In The Earth



b) Geometry For Perpendicular Probe Wires

Fig. 2 - MEASUREMENT OF THE ELECTRIC FIELD IN THE EARTH

antenna off. Detailed data tabulations, indicating all of the components measured, are given in Appendix B.

3. MEASUREMENT RESULTS

As noted earlier in this report, certain electromagnetic field intensity relationships between ELF antenna-generated fields and extraneous (ambient) fields are preferred so that data from the ecological monitoring program can be interpreted reasonably. One would generally prefer that 76 Hz fields exceed 60 Hz fields at test plots by a substantial amount, that 76 Hz fields at test plots exceed those at control plots by a substantial amount, and that 60 Hz fields at test and control plots be roughly the same. A factor of 10 difference (one order of magnitude) may be considered a substantial difference, and a factor of 100 or more would certainly signify that 76 Hz and 60 Hz field intensities are sufficiently different that ecological investigators can reasonably relate their findings to electromagnetic field conditions, presuming all other between-plot factors of ecological importance are well matched.

Table 1 presents a summary of the measurement data. It indicates that the dominant 76 Hz magnetic flux densities at the three test plots significantly exceed the 60 Hz densities, a preferred monitoring condition. The 76 Hz magnetic fields at control plots are also more than two orders of magnitude lower than at test plots, another preferred condition. Finally, the 60 Hz magnetic fields are very low and are comparable at all study plots, a satisfying condition. Similar satisfactory conditions can be seen to exist between test and control plots with regard to 76 Hz and 60 Hz electric field intensities. Therefore, the test and control plots selected by the University of Wisconsin-Parkside investigators for slime mold studies in Wisconsin may be regarded as having electromagnetic field conditions that conform with criteria preferred for studies included in the ELF Ecological Monitoring Program.

Table 1

DATA SUMMARY FOR SLIME MOLD
TEST AND CONTROL PLOTS [1.]

Site		Magnetic Flux Density (Gauss)		Electric Field Intensity (Volts/meter)	
Number	Description	76 Hz	60 Hz	76 Hz	60 Hz
A1	N/S Antenna Test	1.8×10^{-1}	3.3×10^{-5}	1.9×10^{-1}	9.2×10^{-5}
G1	N Ground Terminal Test	4.0×10^{-3}	2.8×10^{-6}	1.2	8.9×10^{-4}
G2	W Ground Terminal Test	7.3×10^{-3}	1.5×10^{-6}	4.4	2.0×10^{-4}
C1	Control	2.6×10^{-5}	1.5×10^{-6}	1.8×10^{-3}	6.2×10^{-5}
C2	Control	2.1×10^{-5}	7.5×10^{-5}	1.6×10^{-3}	1.7×10^{-3}

1.) Values shown are magnitudes determined as the square root of the sum of the squares of the orthogonal field components measured. Data for 76 Hz represent a worst case value determined by summation of the magnitudes for fields produced by the E-W and N-S antennas extrapolated to full operating current (300A). A complete data tabulation is given in Appendix B of this report.

APPENDIX A

SLIME MOLD (PHYSARUM POLYCEPHALUM) TEST AND CONTROL SITES IN THE AREA SURROUNDING THE WISCONSIN TEST FACILITY

SITE A1 -- SLIME MOLD TEST

This site is located at the antenna north leg crossing of Highway 77, 26 meters south - southwest of the U.S. Navy's buried cable marker on the east side of the buried antenna right-of-way, as shown in Figure A-1.

SITE C1 -- SLIME MOLD CONTROL

This site is located approximately 11 1/2 miles east of Clam Lake, Wisconsin on Forest Road 351, 1/4 mile north of Highway 77. The site plot is located 19 meters north and 16 meters east of the Chequamegon National Forest sign found on the east side of Forest Road 351, as indicated in Figure A-2.

SITE G1 -- SLIME MOLD TEST

This site is located at the north end of the north antenna leg ground. It can be accessed by taking Forest Road 195 north from Highway 77 to Forest Road 182, and following the latter east to the travelway leading south to the antenna ground. The site plot is located on the east side of the antenna ground right-of-way. It is 4.2 meters southward from Pole N11 and 5.6 meters to the east as shown in Figure A-3.

SITE C2 -- SLIME MOLD CONTROL

This site is located near the intersection of Forest Roads 191 and 192, approximately 9 miles northwest of Clam Lake, Wisconsin on Forest Road 191. The site plot is located 34 meters east (along Forest Road 191) from the Forest Road 191 marker at the intersection, and 16 meters south of the road center. This plot is 4 meters due south of a large spruce tree. It is illustrated in Figure A-4.

SITE G2 -- SLIME MOLD TEST

This site is located at the north end of the west antenna leg ground. It can be accessed by taking Forest Road 204 north from its intersection with Forest Road 328 to the third travelway entrance on the west side of Forest Road 204. The site plot is located 17.9 meters north of pole N19 and 10.4 meters east from a point directly under the overhead ground cable. It is shown in Figure A-5.

View from Highway 77 looking down the buried antenna right-of-way.

View of site plot from directly over buried antenna cable.

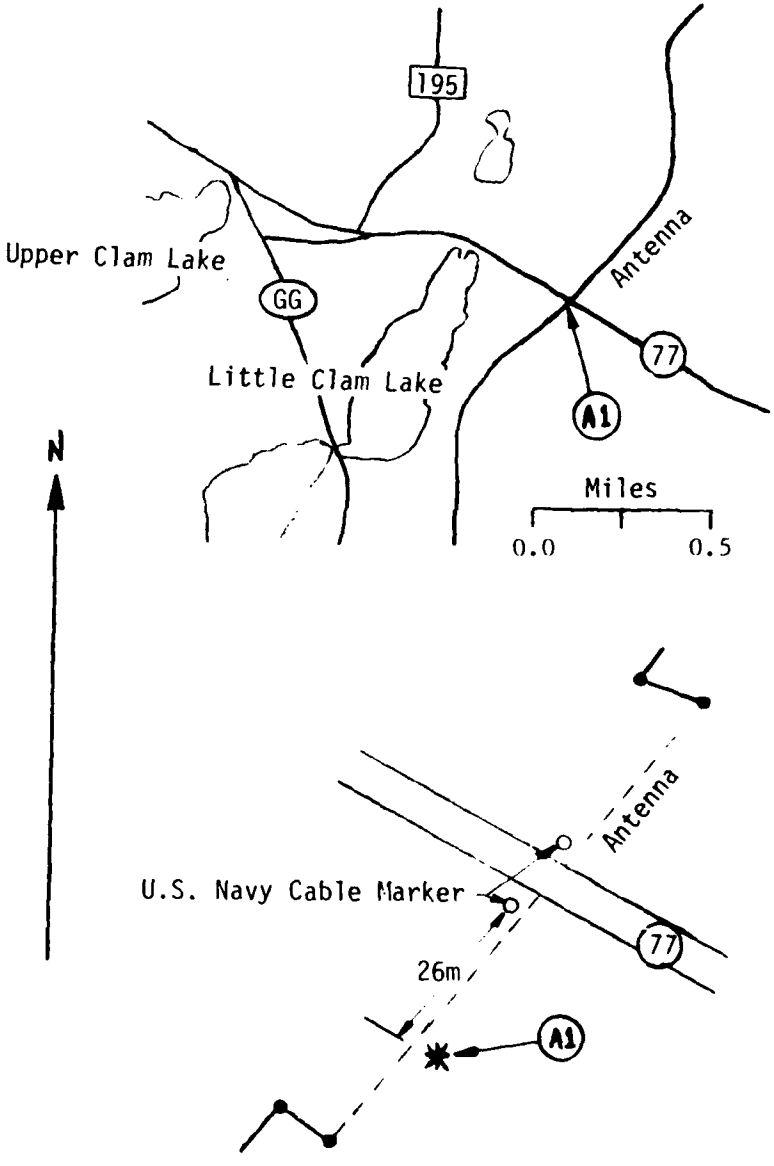
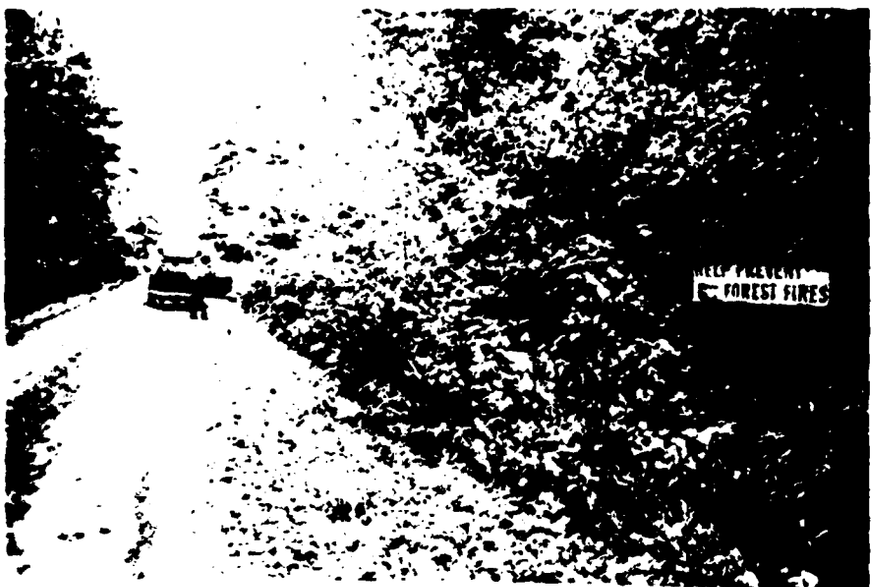


Figure A-1 SLIME MOLD SITE A1

View of National Forest sign looking north along Forest Road 351.



View from Forest Road 351, east towards site plot.

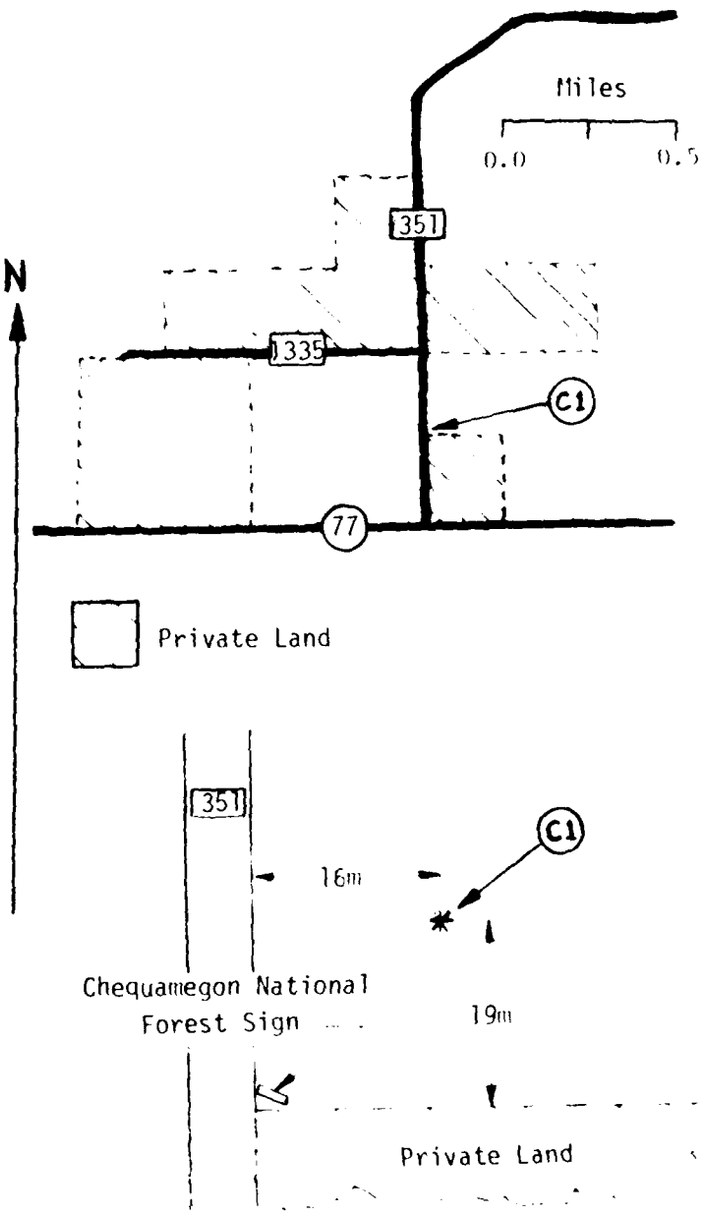
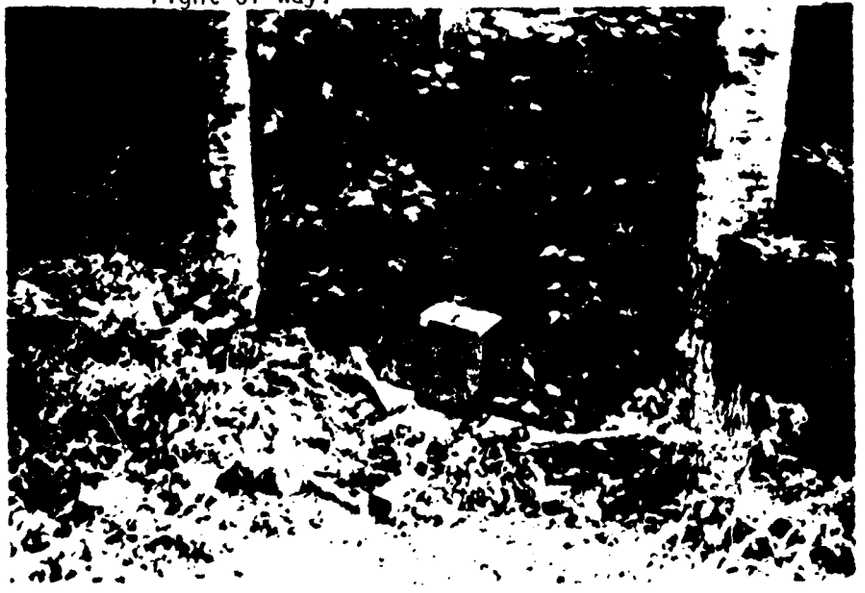
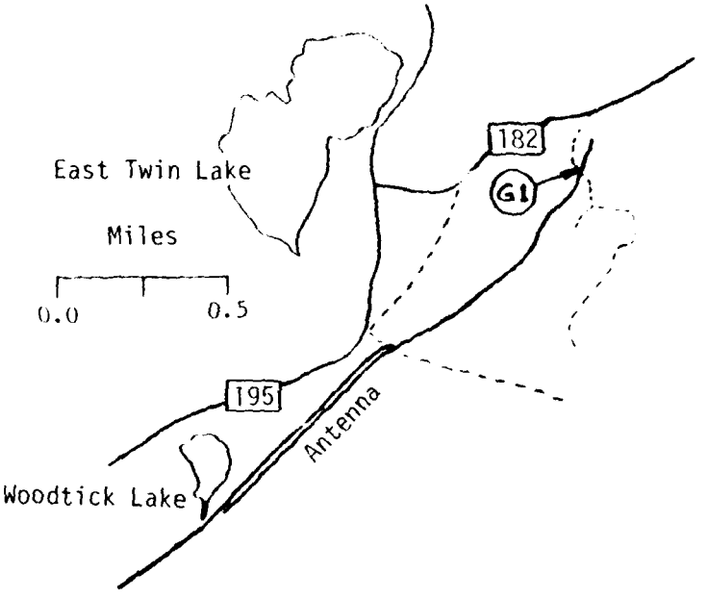


Figure A-2 SLIME MOLD SITE C1

View of north end of the north antenna leg ground. (Pole N11 in left half of picture).

View of site plot from antenna ground right-of-way.





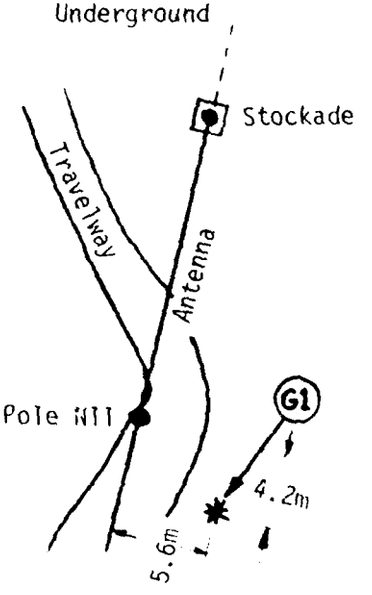
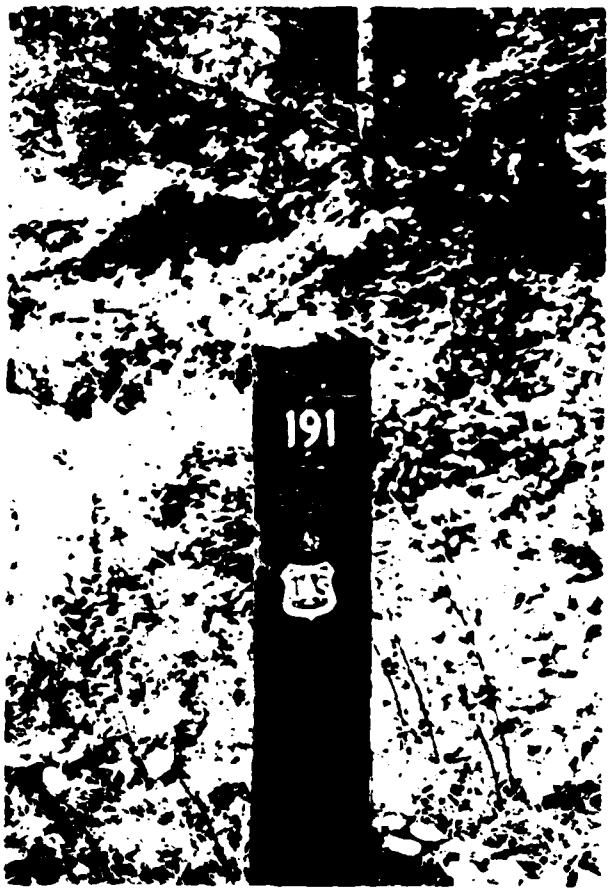


Figure A-3 SLIME MOLD SITE G1



View of Forest Road Marker.

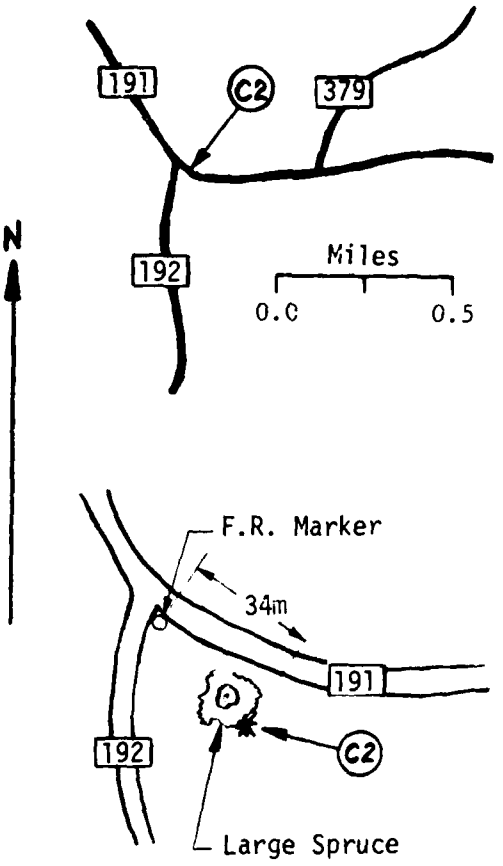


Figure A-4 SLIME MOLD SITE C2

View of site plot.

View of north end of west antenna leg ground.
(Pole N19 is at far right of picture).

View of site plot from antenna ground right-of-way.

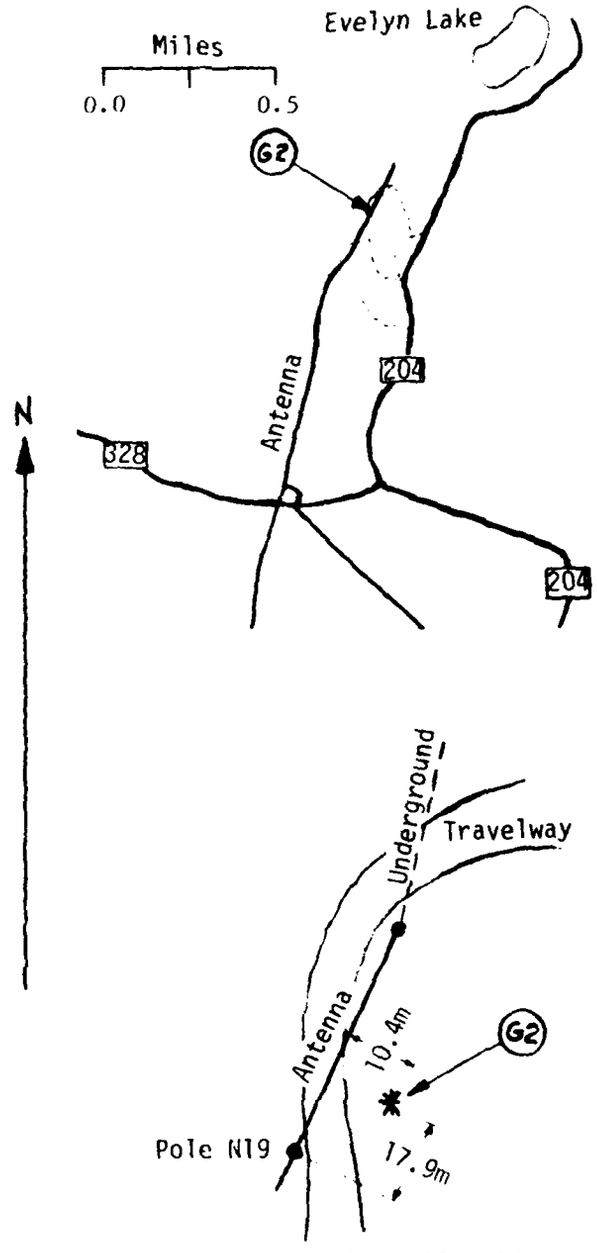


Figure A-5 SLIME MOLD SITE G2

APPENDIX B

DATA TABULATIONS

Table B-1

ELF MAGNETIC FIELDS AT TEST AND CONTROL SITES (SLIME MOLD)

FREQUENCY = 76 Hz[1]

SITE	MAGNETIC FLUX DENSITY[2] ($\times 10^{-3}$ GAUSS)							
	N/S ANTENNA				E/W ANTENNA			
	B_{NS}	B_{EW}	B_{VERT}	$\|B\|$	B_{NS}	B_{EW}	B_{VERT}	$\|B\|$
A1	14.6	58.4	167.	178.	0.38	1.9	5.6	5.9
G1	0.96	2.6	2.8	3.9	0.027	0.082	0.085	0.12
G2	0.019	0.11	0.14	0.18	0.53	5.0	4.9	7.1
C1	0.0047	0.0092	0.0053	0.012	0.0038	0.012	0.0065	0.014
C2	0.0084	0.0037	0.0026	0.0095	0.0076	0.0066	0.0029	0.011

1) Data extrapolated for an antenna current of 300 Amperes

2) B_{NS}, B_{EW}, B_{VERT} are magnetic flux densities in the North-South, East-West, and Vertical directions respectively, except for sites G1 and G2 where B_{NS} and B_{EW} are flux densities in directions parallel and perpendicular to the antenna ground terminal respectively.

$|B| = \sqrt{B_{NS}^2 + B_{EW}^2 + B_{VERT}^2}$, the composite magnetic flux density magnitude.

Table B-2

ELF ELECTRIC FIELDS IN THE EARTH AT TEST AND CONTROL SITES (SLIME MOLD)
FREQUENCY = 76 Hz[1]

ANTENNA	SITE	ELECTRIC FIELD INTENSITY[2] (VOLTS/METER)					
		E_{NS}	E_{EW}	$\|E\|$	$E_{(NS+\pi/4)}$	$E_{(EW+\pi/4)}$	$\|E\|$
N/S	A1	0.18	0.014	0.18	0.12	0.11	0.16
	G1	0.11	1.12	1.12	--	--	--
	G2	0.0060	0.12	0.12	--	--	--
	C1	0.0009	0.0001	0.0009	--	--	--
	C2	0.0003	0.0009	0.0009	--	--	--
E/W	A1	0.0071	0.0023	0.0075	0.0056	0.0039	0.0068
	G1	0.0020	0.034	0.034	--	--	--
	G2	0.16	4.3	4.3	--	--	--
	C1	0.0009	0.0002	0.0009	--	--	--
	C2	0.0003	0.0006	0.0007	--	--	--

1) Data extrapolated for an antenna current of 300 Amperes.

2) E_{NS}, E_{EW} are electric field intensities in the North-South and East-West directions respectively, except for sites G1 and G2 where E_{NS} and E_{EW} are field intensities in directions parallel and perpendicular to the antenna ground terminal respectively. Vertical electrical fields in the earth are zero.

$E_{(NS+\pi/4)}$, $E_{(EW+\pi/4)}$ are electric field intensities measured at angles of 45° with respect to the North-South and East-West directions, respectively.

$|E| = \sqrt{E_{NS}^2 + E_{EW}^2}$, the composite electric field intensity magnitude

Table B-3

AMBIENT 60 Hz ELECTRIC FIELD INTENSITY AND MAGNETIC FLUX DENSITY[1]

SITE	MAGNETIC FLUX DENSITY[2] ($\times 10^{-3}$ GAUSS)				ELECTRIC FIELD IN THE EARTH[3] FIELD INTENSITY (VOLTS/METER)		
	B_{NS}	B_{EW}	B_{VERT}	$\|B\|$	E_{NS}	E_{EW}	$\|E\|$
A1	0.0011	0.0095	0.032	0.033	0.000090	0.000018	0.000092
G1	0.0006	0.0022	0.0016	0.0028	0.000092	0.00088	0.00089
G2	0.0013	0.0005	0.0004	0.0015	0.000038	0.00020	0.00020
C1	<0.0010	<0.0010	<0.0010	<0.0015	0.000051	0.000036	0.000062
C2	0.019	0.0045	0.072	0.075	0.0015	0.00090	0.0017

1) 60 Hz measurements made with both antennas off.

2) B_{NS}, B_{EW}, B_{VERT} are magnetic flux densities in the North-South, East-West, and Vertical directions respectively, except for sites G1 and G2 where B_{NS} and B_{EW} are flux densities in directions parallel and perpendicular to the antenna ground terminal respectively. $|B|$ is calculated as the square root of the sum of the squares of the orthogonal components.

3) E_{NS}, E_{EW} are electric field intensities in the North-South and East-West directions respectively, except for sites G1 and G2 where E_{NS} and E_{EW} are flux densities in directions parallel and perpendicular to the antenna ground terminal respectively. $|E|$ is calculated as the square root of the sum of the squares of the orthogonal components. Vertical electrical fields in the earth are zero.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